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Biodiesel value chain and access to energy in Ethiopia: Policies and business prospects

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ABSTRACT

Similar to many net oil importing Sub-Sahara African countries, Ethiopia's economy is rural and as it stands today it is far from being a fossil fuel based economy. Instead, the economy is largely powered by traditional burning of solid biomass. Despite its small share in the overall energy supply (7%), imported fuel absorbs half of Ethiopia's foreign currency earnings. The common justifications behind the development of biofuels such as energy source diversification, foreign currency saving, rural poverty alleviation through employment and technology transfers were all appealing for Ethiopian policy advisers. In 2007, mostly influenced by the global discourse, Ethiopia launched a biofuel expansion strategy and a massive ad hoc investment promotion of two biodiesel crops: castor and jatropha. In this paper, we synthesize the various biodiesel development initiatives and modes of production, and point out at the gaps in policy formulation and project implementation. Evaluating the prospect and constraints for biodiesel production in Ethiopia, we conclude that most of the prerequisites for a viable biodiesel industry still need to be met. We identify key areas and priorities to further strengthen the development of the biodiesel sector.

Contents

1. Introduction

Energy consumption disparity across the globe is dramatic. Three-fourth of the world's poor consume only 10% of the global energy supply [1]. The majority of those energy-poor households live in net oil-importing Sub-Saharan Africa (SSA) where Ethiopia is ranked at the bottom of the global energy poverty index [2]. Kebede et al. [3] reports that a 1% increase in GDP requires a 0.55% increase in energy use in SSA, suggesting that any increase in the current per capita GDP in SSA relies greatly on an increased use of energy. Observations strongly suggest that energy poverty drags back poverty reduction efforts, particularly in low-income countries [4,5].

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Diversification of energy resources has increasingly been viewed as a way to improve energy access and security.[1] Bioenergy and especially that of biofuel evolved as a natural candidate to diversify energy sources away from fossil fuels. Many African countries (Mozambique, Tanzania, Ethiopia, Angola, Malawi and Zimbabwe among others) embraced the excitement of biofuels and pursued large-scale deals. A few countries (such as Zimbabwe or Malawi) started a number of biofuel initiatives as early as in the 1980s but the combined effects of climate change, volatility of fuel prices and the recent food crisis and global economic downturn have triggered a sense of urgency among policy makers, industries and development practitioners to find sustainable and viable solutions in the area of biofuels. This sense of urgency is reflected in the rapid expansion of global biofuel production, markets and policies over the past few years [7]. However, several critics argue that most investment deals have been carried out in a non-transparent, piecemeal and fragmented manner, and that most (if not all) stakeholders involved have lost from the situation [8].

In that regard, Ethiopia is a relevant example for studying the evolution and potential of biofuels in SSA. Enthralled by the various commonly portrayed opportunities lying ahead of the development of biofuels (such as energy source diversification, foreign currency saving, rural poverty alleviation and technology transfers), the Ethiopian government launched an extensive biofuels expansion strategy and an ad hoc investment promotion program in 2007 for two biodiesel crops: castor and jatropha.[2] These two crops were especially promoted for their expected adaptability and capacity to grow on marginal lands and under drought conditions [9]. A few years later, the government substantially downsized its promotion effort as a result of the overwhelming concern about competition between food and biofuel crop production. An extended review on the food-versus fuel debate is out of the scope of this paper, but interested readers can refer to Rajagopal and Zilberman [10], Mitchell [11] and FAO [12] among others for a thorough review of the macro level studies on the impact of biofuels; and to Oladosu and Msangi [13] for discussions around the interactions between biofuels and food markets.

We argue that these concerns and fears about the development of biofuels are not well-founded in the case of Ethiopia or should at least be more nuanced. First, the biodiesel sector exhibits an underdeveloped value chain that mostly focuses on unprocessed feedstock export. Large-scale production and use of biodiesel is unrealistic in the short-term. Second, oil from biodiesel feedstock offers a potential in remote and dispersed areas where it can be used for cooking, lighting and agricultural equipment, at the local level and at a smaller scale. In contrast to most anti-biofuel views, there is now a revived interest in decentralized renewable energy provision to solve the energy crisis in more-isolated and poorly integrated areas [14]. Some view biodiesels (or vegetable oils in general) as unique local resources in the rural energy mix. For example, Brazilian public policy identifies biodiesels as 'social fuels' for their role in integrating smallholder farmers into the supply chain while making local energy production available for local use [15–17].

In this paper, by synthesizing the various biodiesel business models that are in place in Ethiopia, we aim to show how biofuel investments can be reorganized and strengthened to contribute to the rural energy mix where they are found to be comparatively beneficial. The analysis that follows draws on evidence from key informant interviews[3], government legislation documents, strategy papers and data from company reports. Furthermore, we conducted observational assessments and triangulations by visiting feedstock production sites. Our analysis only focuses on biodiesel initiatives from non-edible feedstocks for two reasons. First, given the fact that the government's strategy excludes the use of edible crops for fuel production, we find it relevant to focus on non-edibles. Second, the ethanol sector to date is a single-stand state-owned bioenergy enterprise that lacks the heterogeneity needed to study the economics of ethanol as an energy source in depth.

Following this introduction, Section 2 analyses current access to energy in Ethiopia, describes the government biofuel strategy and reviews the potential source crops identified as relevant for biodiesel production. Section 3 outlines the framework used to analyze biodiesel potential and current investment initiatives. Section 4 presents the inventory of biodiesel investment initiatives and synthesizes their specific contributions. Section 5 discusses the policy environment, past experience and future prospects. We present concluding remarks in Section 6.

2. Background on biofuels in Ethiopia

2.1. Access to energy in Ethiopia

Ethiopia is a net energy importer and is viewed as the number one "energy poor country" in the world [2]. According to IEA [6], only 23% of households had electricity connection in 2012, with this rate being 11% in rural areas. Looking at public investments, Ethiopia suffers from a persistent lack of infrastructural development, particularly in the area of energy supply [18,19]. Most of the rural areas do not have access to electricity from the local grid, and their energy need is entirely dependent on locally available biomass resources and on expensive imported fossil oil to some extent [20].

Solid biomass has been a prime source of energy (above 91%) for decades (Fig. 1A). Rural energy demand is mainly used for lighting, cooking and the powering of household appliances such as televisions, audio systems and electric motors for grinding food [21]. As shown in Fig. 1B, energy consumed for productive uses such as for manufacturing, mechanical energy for agriculture or irrigation, or transport, is negligible (with less than 1% share in total energy consumption of the country).

According to a recent welfare monitoring survey [22], the lion's share of solid biomass energy (which includes fuel wood, charcoal, dung, and crop residues) is consumed for residential cooking purposes in rural areas (Table 1). When looking at sources of energy for lighting in rural areas (Table 2), kerosene use represents about 60–70% of it, and very few families can afford to use petrol or diesel generators.

A number of studies analyze in detail the health, social and environmental problems associated with the direct burning of solid biomass [14,23]. Reported data shows that in SSA countries, indoor air pollution accounts for the burden of disease in the range of 3.7–6.6%, making it the most important risk factor after

[1] There is no single internationally-accepted definition of energy access but it is generally defined as access to electricity and clean or modern cooking facilities [6].

[2] This paper mainly focuses on biodiesel. Biodiesel is one form of biofuel. In this paper, we use the term biofuels to refer to a broader class of liquid fuels. It includes ethanol obtained from starch bearing energy crops such as sugar cane, grain, or sugar beet and biodiesel obtained from pressing oil bearing crops such as castor oil and jatropha.

[3] The following stakeholders were interviewed: officials from the Ministry of Agriculture and Rural Development, from the Ministry of Water and Energy, from the Ethiopian institute of Agricultural Research and from the Ethiopian Investment Agency; researchers from the Africa Horn of Africa Regional Environmental Centre at the Addis Ababa University; managers from all biodiesel projects (private businesses and PPP); members of civil society organizations.

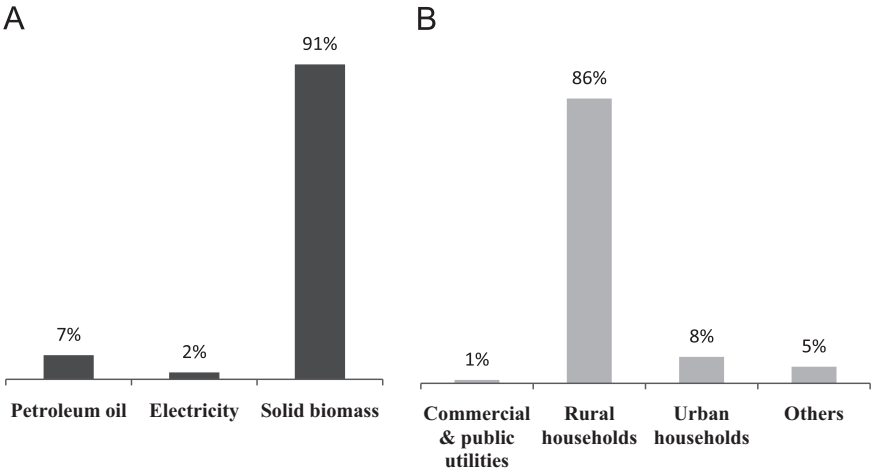


Fig. 1. Sources and consumption of energy in Ethiopia. (A) Energy sources (share in %) (2011) (B) energy consumption (share in %) (2011).
Source: [22]

Table 1
Household fuel sources for cooking (% total energy use).
Source: Computed based on [22].

	Rural		Urban	
	2000	2011	2000	2011
Collected fuelwood	76.4	87.23	16.6	16.59
Purchased fuelwood	2.4	3.6	41.3	44.72
Charcoal	0	0.23	8.3	17.54
Dung, leave and other residues	17.2	8.47	6.3	2.72
Kerosene	0.3	0.17	21.5	4.93
Butane	0.1	0.1	1.4	1.05
Electricity	0.1	0.1	2.2	6.18
Others	3.6	-	2.4	0.06

Table 2
Household fuel sources for lightening (% total energy use).
Source: Computed based on [22].

	Rural		Urban	
	2000	2011	2000	2011
Kerosene	74.6	64.41	28.6	7.69
Electricity (private)	0.50	1.79	31.8	36.82
Electricity (shared)	0.40	3.23	38.2	51.55
Fuel wood	24	14.11	1.1	0.40
Electrical battery	–	15.79	0.30	.2.83
Others	0.40	0.20	0.30	0.70

malnutrition, HIV/AIDS, and lack of safe water and adequate sanitation [24,25].

Ethiopia's overdependence on biomass fuel and the insignificant use of energy in the commercial, industrial and utility sector of the economy clearly demonstrate the energy poverty of the country.[4] Energy poverty evidently slows down rural development to a great extent. The rural economy being the driver of the country's development, its overreliance on a backward energy supply system supposedly undermines productivity of land and labor.

[4] Energy poverty is a multidimensional concept but it is generally understood as households' lack of access to modern energy services [26].

2.2. The Ethiopian biofuel strategy

Given Ethiopia's rudimentary access to energy, there is some clear economic sense to promote biofuels. From the government's perspective, a strong biofuel sector may be attractive not only to diversify energy resources but also to improve energy access, to reduce import dependency, to save foreign currency, to promote the development of rural areas through investment and job creation and to reduce greenhouse gases emissions [27]. From the private businesses perspective, engaging into biofuel activities may sound appealing for two reasons. First, the availability of low-cost land lease and labor makes Ethiopia attractive for investment. 3.5 million hectares of land are said to be available for crop cultivation [28].[5] Second, the country's diverse agro-climatic conditions are favorable to grow biofuel crops, although this should be nuanced by the difficult accessibility to agriculturally suitable areas that are likely to limit biofuel expansion [29]. From the perspective of rural households, biofuels can not only improve energy and electricity access but also offer farmers employment opportunities and additional sources of income in producing areas.

Given these considerations, the Ethiopian government has taken steps to support the emergence of biofuel value chains and has launched a Biofuel Expansion Task Force that led to the development of a Biofuel Strategy document in 2007.[6] Policy makers also created a high-level Biofuel Promotion Committee and an Exclusive Biofuel Development Department under the Ministry of Mines and Energy (MoME). The MoME started managing and monitoring an ad hoc investment promotion program of two biodiesel crops (castor and jatropha) aimed at foreign and local investors while the Ministry of Agriculture and Rural Development (MoARD) administers and monitors land allocations for biodiesel investment, under the overall agricultural investment promotion framework. At the same time, in 2007, the government established a 10% blending requirement of ethanol with petrol, and biodiesel with diesel [27]. While the ethanol target was successfully reached in 2012 in major cities, progress regarding the biodiesel target is meager. The government manages

[5] This figure is relatively modest compared to government estimates that have identified 23.3 million hectares (20% of the total country area) as being available for both castor and jatropha [63]. These should however be taken with caution given that the methodology behind this assessment is unclear and that land purportedly available in some regions is disproportionately large compared to the region's size.

[6] To date this document has still not been enacted as legislation.

a vertically coordinated ethanol production system while biodiesel is left largely to private operators.

From 2007 onwards, the Government has specifically supported the economic attractiveness of biofuel production and the expansion of investments in the sector by providing incentives to investors which include tax holidays, low-cost land leases, and long term credit facilities, among others. The government's interest in biofuels was later reemphasized in the Growth and Transformation Plan (GTP). Over a five year period (2010–2015), Ethiopia's GTP foresees increasing the production of ethanol to 194.9 million liters, biodiesel to 1.6 million liters, and an increase in blending facilities to 8 for ethanol and to 72 for biodiesel. As outlined, the main objectives for promoting biofuels are to create clean energy source diversity, serve as substitute for petroleum import and create jobs for local people. The document also recognizes the important contribution of involving the private sector and smallholder farmers into the development of biofuel.

However, both the policy environment and the government strategy around biofuels policies have been unstable and somewhat contradictory. Indeed, soon after a few years of enthusiasm, Ethiopia substantially downsized most of the incentives that were in place to promote their production. The key reason behind this policy shift away from biofuel was an increasing concern over competition between food and biofuel crops and over bad management of land investments. This issue was raised by both the international and local communities and led to a substantive narrowing of land being allocated to investors for the production of biofuel feedstock. As a result, only land that is considered to be 'marginal land' can now be used.

In considering the spontaneous withdrawal of land allocation for biofuel investment activities since the year 2010, one may wonder about the influence of civil society organizations (CSOs). While the power of CSOs' involvement in the development policy of Ethiopia in general can be contestable, we observe two areas (or channels) in the area of biofuels through which CSOs have influenced biofuel activities and indirectly policies. The first is through lobbying against private companies that invest in biofuels. In one example that has drawn attention, a local NGO has vocally lobbied against two biofuel companies to influence and deter farmers to engage in contracts with these companies. The second channel is the communication of international NGOs or other agencies through the media and internet about ill effects of biofuels on food prices, land 'grabbing' and deforestation [30,31]. During our qualitative interviews, we found cases of cautious behaviors of government officials influenced by the information found on internet, despite weak checks of credibility or authoritativeness of those sources. This leads us to presume that pessimistic views on biofuels disseminated through the international communication platforms have played a role in constraining their development in the country.

To further emphasize the ad hoc characteristic of biofuel policy-making in Ethiopia, we should also stress that neither the initial endorsement of the expansion policy, nor the subsequent downcasting of the promotion of biofuel crops were backed by adequate research. Moreover, as of today, there are divided objectives and responsibilities for coordinating biofuels among the ministries involved, especially the MoME and MoARD on one side and the Ministry of Natural Resources Development and Environmental Protection on the other.

2.3. Non-edible biodiesel sources in Ethiopia

A variety of non-traditional oil bearing crops including jatropha, castor bean, moringa, pongamia, palm and croton grow in Ethiopia. Although castor and jatropha are the most known and cultivated biodiesel feedstocks, other crops such as moringa for example are believed to be promising for Ethiopia [32]. Jatropha, castor and pongamia have been identified by the government as prime biodiesel feedstocks [27].[7] The direct vegetable oil (the non-edible oil extracted from the plants, before processing it to biodiesel) represents a potential resource for a variety of uses such as cooking, lighting, as an export commodity for foreign markets, or for localized electricity generation.

Table 3
Oil yield and water requirement of the major oil bearing crops.
Source: Computed based on [78,79].

	Required rainfall (mm yr^{-1})		Range of oil yield estimates (kg ha^{-1})	Average maturity period (years)
	Low	High		
Castor	500	650	495–2100	0.3–0.4
Jatropha	150	300	600–1700	3–4
Palm[a]	1800	2500	5000	2–3
Pongamia	150	300	1500	6–8

[a] As stated in the introduction, we have excluded palm oil from our discussion consistent with the Government Strategy to focus on non-edible biodiesel oil.

Both jatropha and castor grow on marginal soils and are claimed to help combat desertification [33,34]. This, together with the fact that they are toxic non-food crops which do not compete directly with food, has brought them to the forefront as biodiesel feedstock. Ethiopia is said to own abundant land where jatropha can grow. A map of suitable areas to grow jatropha as identified by the government in presented in Appendix. According to Wahl et al. [35], Ethiopia is one of the African countries with the largest area of jatropha planted (approximately 20,000 ha). However, most of these areas are not newly cultivated plantations but rather either made of existing hedges or used for environmental rehabilitation purposes.

As shown in Table 3, oil bearing crops vary greatly in their agronomic requirements (for example water), maturity periods and yield levels. Alternative uses of non-edible oils need to be identified and compared in terms of the economic and social benefits accruing to them. Gaul [36] compares the cost effectiveness of jatropha for rural lighting and cooking in Indonesia and finds that jatropha-based oil cannot compete with wood-based cooking. Methodologies and countries vary across studies but the economic attractiveness of jatropha are reported to be negative or moderate at best [37–39].

In contrast, others associate the negative claims about jatropha with the lack of adequate technical understanding of its agronomic and multiple uses that are not yet fully discovered [40,41]. The uncontested benefit of jatropha is its substitutability with kerosene in remote rural communities where road transport is difficult and the supply of energy from other sources is excessively expensive [37,38,42].

Castor is believed to be an indigenous plant to Ethiopia. It grows both as wild and cultivated and it is a high-value industrial crop [43]. Being an oil bearing seed (with 45% oil content), it is a crop with a commercial value. There exists a dynamic international market for its oil and it is said to have good export potential and represent an interesting prospect for Ethiopian production [44]. It can be cultivated with common agronomic practices accustomed to current farming system in Ethiopia. Noteworthy, it has been categorized as an invasive plant that may threaten

[7] The pongamia tree, native from South-East Asia, has also raised high expectations because it is said to tolerate drought and poor soil types and has low crop maintenance and harvesting requirements. Its development and adaptability to the Ethiopian context are still at the initial stages of testing in the West (Beneshangul-Gumuz region).

biodiversity and its cultivation is not supported from an environmentalist perspective. With large, remote and non-urbanized areas, Ethiopia is one of the major biodiversity hotspot countries in the world [45,46]. To what degree the introduction of castor would affect Ethiopia's strong biodiversity base should be further researched. As Fisher and Christopher [45] note, biodiversity conservation aims should not compromise development goals and vice versa. To better understand and take into account the environmental externalities from castor production, the biodiversity (or environmental) costs of its invasiveness nature should be weighed against the economic and social benefits of using castor as a biofuel source. Available studies so far focus mostly on economic analyses and future research adopting a cost-benefit approach would be valuable.[8]

3. Conceptual framework: Configurations in the biodiesel value chain

Similar to other agricultural investments, there are several ways in which rural households can potentially engage in the biofuel supply chain: (a) through direct employment in large-scale plantations, (b) indirectly through leasing land to biofuel producing companies, (c) through contract farming schemes with processors (or feedstock exporter) companies, or (d) through collective community-based small-scale oil extraction schemes.

The perception that fuels produced from biomass can become tools for economic development by helping create and maintain agricultural jobs and by increasing farmers' incomes has been a dominant view in development circles [47]. However, biofuel projects differ enormously in their intent, feedstock choice and management practices [48]. The impact of biofuel production on rural development strongly depends on national and local conditions, on the choice of specific technologies and feedstocks [49] and on the way the value chain is organized [50]. It is therefore important to define a typology that identifies, analyzes and classifies the various ways businesses organize biodiesel production, processing, distribution, marketing and utilization, and how the economic value created by biofuels is allocated across value chain participants.

von Maltitz and Setzkorn [48] classify biofuel production projects in Africa using two dimensions. First, projects can fall under three distinct size categories that are a function of ownership and management, i.e. smallholder (typically less than 10 ha), commercial farmers (tens to thousands of hectares) and corporate plantations (mostly thousands of hectares). Second, two distinct type of projects are distinguished based on the end use of biofuels i.e. the external market on one hand and rural development and local self-sufficiency on the other. Altenburg uses a similar classification of biofuel value chain configurations and groups them by chief organizing actors and production risk takers. The three categories he uses are government-centered cultivations, farmer-centered cultivations and corporate-centered cultivations [50]. Following these authors' approach and our field observations, we group the ongoing biodiesel projects in Ethiopia into four specific modes of production: (1) government-centered, (2) corporate-centered, (3) environment-centered, and (4) public–private partnership (PPP).

The proposed typology provides a systematic framework to understand biofuels business risks as well as concerns about societal and environmental externalities. Sometimes local initial conditions dictate the emergence of specific modes of production and each of them may support different aspects of rural development. For example, a given arrangement can be more effective in transferring technology and creating jobs but may have low added value in terms of value chain development, resulting in a particular mechanism of rural wealth creation and distribution.

First, as predicted by standard economic theory, organizing biofuel production through a government-centered approach is often justified when biofuel is a strategic commodity that accrues a high social benefit or when the investment involves considerable initial risk and thus will likely fail to attract private investors [51]. Although bioenergy commodities do not necessarily fulfill these public good characteristics, state-owned bioenergy enterprises are common in countries like China [52,53]. In such cases, the system is entirely or partially supported to achieve general societal goals through public funding even if doing so may not always be economically viable [54,55].

Second, in contrast to government-centered production, corporate-centered production aims to optimize economic benefits and thus tends to be organized when economic returns show a positive balance given the prevailing market and policy (dis) incentives. Profit maximization will here depend on the industry structure, market power, competition and entry barriers.

Both government-centered and corporate-centered modes of production can practically be organized as large scale capital intensive plantation schemes or can be integrated with an existing smallholder production system through a form of outgrower scheme [56]. Outgrower schemes are often argued to be more pro-poor than large scale capital intensive plantations, especially when they result in technology spillovers to other crops [57–59]. They are best seen as a way to support rural income generating activities and farmers' inclusiveness in the biofuel value chain.

Nevertheless, achieving commercial viability in outgrower schemes may be challenging because of large transaction costs associated with managing production from widely dispersed small farms and the problems of securing a sufficient supply of biofuel feedstock as observed in an Ethiopian castor outgrower scheme.[9] This sometimes leads to a mixed organizational form of commercial plantation along with outgrower schemes to supplement supply shortages and diversify risk [60].

Third, environment-centered modes of production are implemented by NGOs or community-based organizations to rehabilitate degraded areas and hence their main objective may not be to attain commercial viability. Their work ranges from not-for profit rural afforestation programs to rural entrepreneurship development programs, all of which integrating some form of biofuel production [48,61].

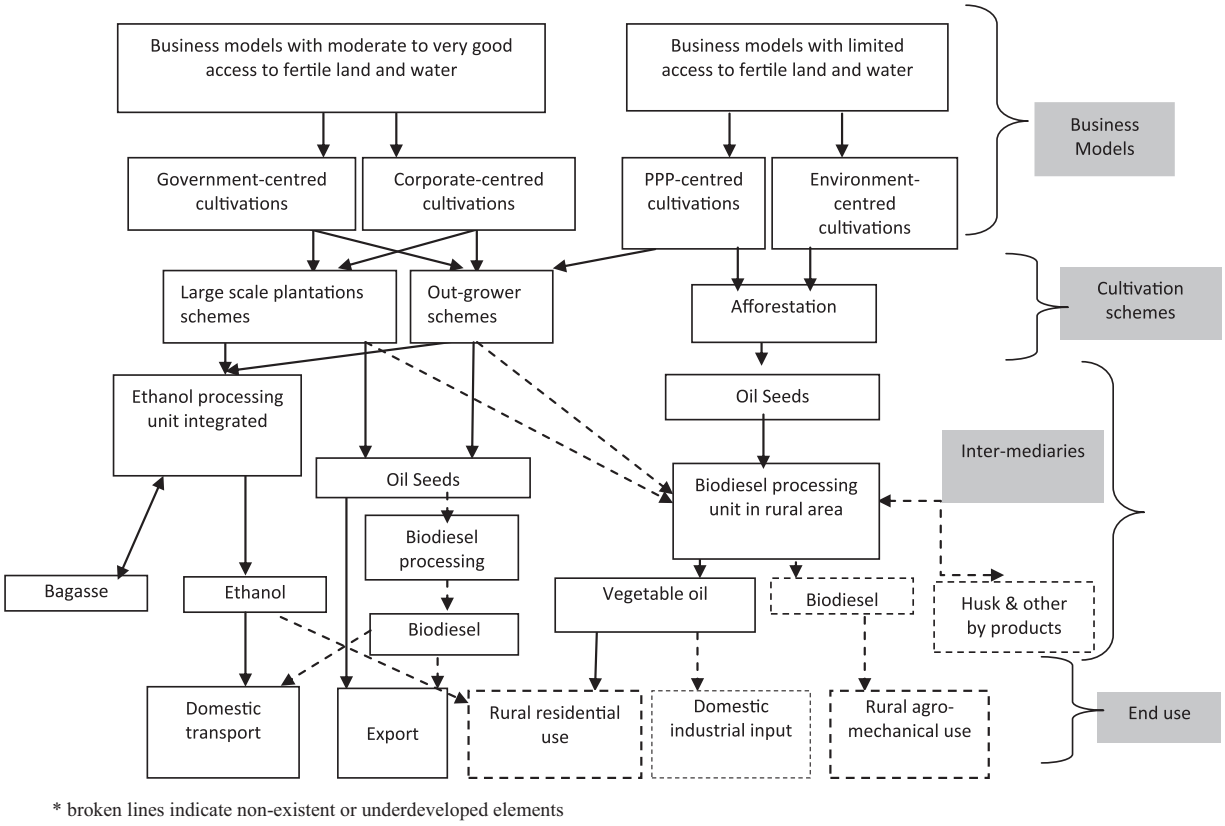
Finally, biodiesel value chains can also be organized through a PPP mode of production. They can be formed to promote sustainable production that brings welfare benefits to rural areas through the involvement of local community groups and government agencies, and at the same time ensure that technological transfers and spillovers are passed on through the involvement of the private sector [62]. As Poulton et al. [63] argue, the revived interest in PPPs in Africa mainly seeks to improve the performance of poorly functioning agricultural value chains which is a prerequisite for a viable biofuel sector to emerge.

4. Biodiesel initiatives and the missing elements

The framework outlined in Section 3 is applied to describe the Ethiopian biofuel sector and is represented by a diagram in Fig. 2.

[8] Since they go beyond the objectives of this paper, the externality effects are not covered here.

[9] From our interviews with biofuel companies operating in Ethiopia, we learned that some projects were cancelled because of these reasons.



* broken lines indicate non-existent or underdeveloped elements

Fig. 2. Framework of biofuels business models in Ethiopia.
Source: Developed by the authors.

Table 4
Biodiesel projects in operation in Ethiopia (2012).
Source: Data collected from the authors' own survey.

Type of business model	Cultivation scheme	No of projects	Type of feedstock specialized	Total area (ha)	
				Total allotted/or leased ('000 ha)	Under cultivation ('000 ha)
Corporate-centered	Large scale plantations[a]	3	Jatropha, pongamia, castor	66.7	8
	Outgrowers[b]	1	Castor	Not applicable	15–30
	Mixed outgrower with plantation	2	Castor	3	3
PPP	Mixed outgrower with plantation	1	Jatropha, candlenut, croton	15	7
Environment-centered	Afforestation[c]	NA	Jatropha	Data unavailable	Data unavailable

[a] All are foreign firms.
[b] Cultivation is integrated with farmers' own plots which makes it difficult to estimate the exact land allocation under this scheme. From [80], 10–20 thousand households cultivate on average 0.15 ha each. This approximately gives a total of 15–30 ha of land allocated to castor under this scheme.
[c] In some cases, farmers are encouraged to plant jatropha as fences and collect the seeds.

The key determinant of business models and cultivation schemes is access to natural resources such as fertile land and water. Large scale plantations and outgrowers (left column) have better access to resources while PPPs and environment-centered activities (right column) tend to operate in less fertile areas. The end use of products also differs across scales and cultivation schemes. On one hand, large scale operations mostly target export markets and the domestic transport sector. On the other hand, the supplies for rural use and domestic industrial input is expected to be realized from PPPs and environment related projects. However, to date, these end uses have not been materialized.

As mentioned in Fig. 2 and detailed in Table 4, four different biofuel business models can be identified in Ethiopia. These are: (a) corporate-centered large-scale commercial plantations or out-grower schemes that are spread out geographically, grow castor, jatropha and pongamia, and are mostly targeted towards the export market; (b) a public–private partnership established in a northern region of Ethiopia (Tigray), that mostly grows jatropha, castor and some croton, with an additional objective of rehabilitating vast degraded areas and providing oil for cooking and lighting in rural areas; (c) environment-centered local not-for-profit initiatives with the main objective of afforestation of

Table 5
Synthesis of biodiesel business models encountered and their present characteristics.
Source: Data collected from the authors' own survey.

Parameters of interest	Corporate-centered mode of production		PPP mode of production	Environment-centered mode of production
	Commercial plantation	Outgrower scheme		
Region of operation[a]	Oromia, Beneshangul, Afar, Somalia	SNNPR	Tigray	Tigray, Amhara
Technology transfer	XXX	XX	XX	X
Scale of operation	XXX	XX	XXX	X
Job creation	XXX	X	XX	X
Scale of initial investment	XXX	X	XX	X
Environmental rehabilitation	Inexistent	Low	Positive	Positive
Biodiversity	Negative	Positive or Negative	Positive	Positive
Land type	Marginal[b]	Farmer's farm	Degraded	Degraded
Product targeted	Bio-diesel	Bio-diesel	Oil as kerosene replacement or cooking fuel	Oil as kerosene replacement or cooking fuel
Target market	Export market	Export market	Domestic market	Domestic market

Note: Based on experts' opinion and detailed interviews, the X scale in each cell indicates the importance of the different biodiesel business models in terms of the different parameters, where X is important, XX is more important and XXX is most important.

[a] See map of the Ethiopian regions in Appendix (Fig. A1).
[b] Degraded land refers to infertile soil. Marginal land refers to land in remote areas.

degraded lands with jatropha and secondary objectives to promote community-operated vegetable oil extraction schemes in areas where conditions allow it and (d) the government-led scheme that organizes the production of ethanol.[10]

We have to highlight that there is a wide discrepancy between the number of registered entities that have requested a license to undertake biodiesel production and the number of entities that are actually operating. According to 2012 data from the Ethiopian Investment Agency, 38 companies have been granted a license to cultivate energy crops for biodiesel production while our data suggests only seven developers are in operation. The government has leased a large area of land to commercial plantations but to date little has been cultivated relative to the total allocation. This finding is similar to the result reported in [64]. While no clear evidence is available, this outcome is probably the consequence of both an unstable policy environment and speculative behaviors on the investors' side.

The synthesis in Table 5 illustrates how each different configuration of the biodiesel production models presents advantages in certain aspects compared to the other configurations. There are inevitable trade-offs in the choice of these business models. For example, a given arrangement can be more effective in transferring technology and creating jobs but it may have adverse environmental effects. The technological and employment gains of a given mode of cultivation have to be weighed against the environmental and biodiversity losses in order to devise compensation policy instruments when necessary.

Like most traditional types of foreign-led investments, the corporate-centered plantation schemes are found where large areas of land are available with sufficient access to river or rainfall water. These businesses are demand driven i.e. a sufficient market that translates to effective demand is necessary for a given product to be developed. Given the low domestic energy purchasing power and the low degree of infrastructure, private businesses in Ethiopia essentially depend on the foreign market to run their companies. As a result, most only focus on feedstock export instead of developing the domestic supply chains. These enterprises have no in-country oil processing or refining units installed. Regardless, they operate on a large scale and pledge new job creation opportunities. Unlike the large-scale export-focused feedstock operations, reports show that if biofuel production, processing and utilization can be localized, it can help accelerate access to energy in rural Ethiopia [65].

Under the PPP scheme, poor rural communities benefit from reforestation schemes that use public food security safety net funds to pay wages in cash or in kind to food-insecure workers. These workers often derive additional cash benefits from the company in exchange of collecting and selling the seeds. However, the purchase prices of seeds is typically not attractive enough to obtain sufficient supplies from the farmers. Since the benefits of the PPP and environment-centered cultivations in terms of rehabilitating degraded areas are strong, linking such environmentally desirable biodiesel projects with Clean Development Mechanisms (CDM) may help achieve both economic and environmental benefits. The Intergovernmental Panel on Climate Change defines CDM as a mechanism under the Kyoto Protocol through which developed countries may finance greenhouse gas emission reduction projects in developing countries, and receive credits for doing so which they may use to extend the mandatory limits of their own emissions [66]. CDM projects are expected to generate an environment added value (i.e. the project emits lower greenhouse gas than the baseline scenario). Given their added environmental benefits, projects can only be eligible for CDM financing if the project cannot be commercially attractive without the additional revenue from CDM. In practice however, a number of problems can undermine the progress of CDM projects; high brokerage and transaction costs, institutional barriers in host countries, a shortage of demand for CDM projects and a risk of fraud when benefiting projects that exaggerate their reduction in carbon emissions and that should actually not be eligible [67].

Despite the above mentioned challenges, the current increasing redirection of the international carbon market towards renewable energy can be an opportunity for poor countries that aim to develop their renewable energy bases. CDM registered renewable energy projects are reported to show positive economic and environmental impacts in a number of developing countries [68,69]. There are no registered CDM projects in Ethiopia but

[10] As outlined in the introduction, the involvement of the state in the production of biofuels only concerns ethanol from sugar cane and we therefore leave this business model out of our detailed analysis of the biodiesel value chain.

there is a considerable unexploited potential in the energy sector and afforestation programs that can be eligible for CDM financing [70]. According to UNDP [70] and Hoch [71], the main reported hurdle in Ethiopia is the lack of awareness both among domestic institutions and foreign investors.

5. Discussion

In the background section, we show that energy poverty in Ethiopia is largely rural. The major obstacle of extending access to modern energy for rural communities is the dispersed nature of population settlement and the remoteness of villages [21]. In such circumstances, off-grid energy services that use direct non-edible vegetable oil can be more feasible than grid-connected systems.

One possible pathway in which the cultivation of non-edible oil bearing crops can contribute to the rural energy mix and help poverty reduction is through local production, processing, marketing and utilization of such oil bearing crops. The final product in this setting would be oil pressed locally for cooking, lighting or small-scale mechanical uses. It can therefore contribute to improving access to modern energy while fostering a "green economy" development strategy, and increasing living standards by generating additional income sources [72,73].

To the extent that decentralized non-edible oil production is an option, it requires specific attention towards addressing financial, institutional and technological hurdles. In villages where access to modern forms of energy is limited or non-existent, access to markets, technologies and financing is often also restricted [39]. Lack of infrastructure such as road and communication facilities are major barriers that hinder the expansion of corporate-centered profit oriented types of businesses in remote villages. Overcoming these multiple hurdles may need a coordinated effort of several actors: business operators, NGOs, research centers, the government and the community.

The practical applicability of a coordinated effort to develop a local biodiesel value chain can be illustrated with two examples of biodiesel projects. The first project had the objective to establish a factory producing oil from jatropha and was implemented in the Amhara region of Ethiopia by the Ministry of Water and Energy, the Horn of Africa Regional Environmental Centre and a community level NGO.[11] The region hosts a wide area of endemic jatropha plants and farmers were organized to collect the seeds to be processed at a locally owned private processing plant. The oil was intended to be marketed locally and used in cooking stoves. Since cooking appliances suitable for vegetable oil are not currently available in the country, an effort was also made to import a prototype stove and manufacture it locally in order to minimize the cost. Future production of the appliances and oil pressing equipment is planned to be organized through local entrepreneurs and is believed to create additional sources of employment and income. The second examples involves a company engaged in a PPP with the regional government of Tigray in northern Ethiopia that has imported a biodiesel processing plant with the objective to supply biodiesel to the local communities that collect the castor and jatropha oil seeds. However, it should be noted that despite these encouraging steps and the significant potential, in practice progress in these two cases has been slow and hindered by a lack of capacity and technical problems both with machinery and with incentivizing farmers to collect the seeds.

The contribution of non-edible oils can also be enhanced by corporate-oriented cultivations and through large-scale commercially oriented biodiesel supply chains targeting both the local and global markets. At present, production in these settings is still at early stages. Production and yields have been low and most commercial farms engaged in production have started exporting castor seeds to foreign markets for industrial purposes (albeit in small quantities). There are cases where private foreign investors have: (a) withdrawn right after having received land concessions because of excessively high initial investment costs (this has mostly been the case in marginal areas); or (b) terminated operations in a short time despite substantial investment because of low yields, internal company problems, lack of support from the local community, the global financial slowdown, or other problems. This has enlarged the skepticism among many officers responsible for facilitating biofuel investment at the grassroots level in Ethiopia and has created doubts about the ability of the companies to bring the intended capital flow and employment opportunities.

While some foreign investors driven by the global interest in renewable energy and biofuels have engaged in biodiesel crop production targeted to the export markets, the number of such cases has been limited. The number of successful ventures is even further limited due to the reasons outlined before. Since their introduction by the government in 2007, biofuel policies have been targeting the national market, towards the diversification of energy resources and improvement of energy access. On the global scene, the biofuels debate has been polarized for long. Because concerns have been further rising in recent years, especially since the world food price crisis of 2008, we do not expect the influence of future international biofuel policies on the Ethiopian setting to increase further. This prediction is also reinforced by the fact that the European Union (the largest producer of biodiesel), is currently renegotiating its biofuel policy and is expected to reduce the maximum allowed share of biofuels in total renewable energy [74].

Regarding further prospects, this leads us to conclude that in the short term, large-scale production of biodiesel feedstock as well as bio-diesel use in the transport sector is unrealistic. This is because of the absence of essential preconditions for a full-fledged commercial biodiesel industry such as: highly productive, stable and reliable feedstock; the presence of valuable by-products; a large enough market and a well-functioning value chain. The desirable option in the short term appears to be the strengthening of rural entrepreneurship towards non-edible oil production that can directly be used for cooking, lighting or further processing into other forms of by-products.

The key priority areas the government should focus on if it is to fulfill its stated ambition to strengthen the long-term development of biodiesel initiatives include research on oil-bearing crop productivity, investment in technology, and facilitating financial services to rural entrepreneurs. We identify three specific areas where the current biofuel strategy can be improved. First, there is strong evidence that the benefits of biofuel investments are magnified if investments are accompanied by technology spillovers to other agricultural activities [28]. Research institutes should include non-edible oil bearing crops into their existing research priorities and investigate how these crops can contribute to improve farm productivity. Biodiesels can improve food productivity when produced together with good crop management practices [75] or when they can be used as an energy source for farming operations [76].[12] The role of research would then be to determine technologies that can create profitable complementarities between food and biodiesel crops. Related to that, research can help determining mechanisms to integrate oil-bearing tree plantations programs into existing afforestation and reforestation

[11] The Horn of Africa Regional Environmental Centre (HoA-REC/N) is a regional network housed in the Addis Ababa University that focuses on environmental concerns and sustainable energy options within the Horn of Africa.

[12] Johansson [76] argues that since the productivity of small-scale farms that are independent of fossil fuels (by using organic methods and draught power) is low, the introduction and use of biodiesel at the local level to substitute draught power can bring positive complementarities.

programs, and further strengthen forest-based bioenergy production practices.

Second, the current strategy lacks specific guidelines on the biofuel supply chain development and provides little attention to the importance of decentralized rural micro energy crop production, processing and utilization. We strongly suggest for policy makers to craft a framework identifying actors in the whole supply chain, factors that limit actors from delivering their responsibilities and interventions required for building capacity. The strategy should especially take into account how biofuels-processing technologies can be accessed by farmers, not only to respond to their energy needs but also to sell any surplus and hence increase their incomes. At the initial stage of product development, limited income in rural areas is expected to constrain the response and growth of private suppliers. Therefore, the strategy needs to point out ways of supporting the early development of bioenergy initiatives in rural areas that focus on local processing and utilization of energy crops. One way this can be done is by providing credit facilities to selected projects chosen not only based on financial feasibility but also in terms of their potential towards technology transfer, job creation and contribution to the local energy supply.

Third, the strategy should foresee the establishment of a proper monitoring and feedback system, with proper collaboration between the national and local government levels and where emerging issues could be addressed and incorporated into the biofuel strategy. Consultations with local officials, farmers and pastoralists should be ensured to guarantee free and informed consent of the local community in relation to biofuel production in its locality and even to encourage its participation in such programs.

6. Conclusion

Access to adequate and quality energy is critical for rural Ethiopia. In this paper, we have reviewed the biofuel investment initiatives and their potential in Ethiopia. The development of ethanol is administered by state-owned enterprises and has substantially expanded in recent years. Emerging biodiesel initiatives are mostly run by foreign firms and a few local private firms, and their progress is slow. Our observations suggest that although the country is endowed with a wide variety of non-edible biodiesel sources, and various forms of business models are in place, a range of factors have hindered their effectiveness in achieving their intended goals. The sector exhibits an underdeveloped value chain that mostly focuses on unprocessed feedstock export to external markets. Large-scale production of biodiesel as well as biodiesel use in the transport sector as envisaged by the government strategy is unrealistic in the short term.

Several reasons explain the unstable biofuel environment and the failure of some of the feedstock projects. From the policy side, there is a lack of clear guidelines on how to create the domestic supply chain for the main products and co-products of non-edible oil-based energy supply. Biofuel policy must not be ad hoc as it has been until now but should instead be research and evidence-based. The country also lacks a proper enabling investment environment in terms of accessibility, infrastructure and facilitative institutions. This is more pronounced in marginal areas where investors are allowed to start commercial operations.

A number of private companies are unable to realize their projects as a result of the unfavorable policy environment and huge initial investment costs related to marginal areas. From the private sector side, there has also been a considerable unpredictability resulting from speculative behaviors, poor understanding of the local context, and lack of economic viability or internal company problems. This affirms the need to promote 'responsible investors' that are dedicated to the reduction of poverty and the creation of new opportunities in terms of knowledge or technology transfers, markets and jobs [77].

Nonetheless, the potential to develop marketable non-edible based biodiesel products and co-products does exist within the country. Businesses should not only focus on the foreign market for raw feedstock supply but must look for innovative value chain development of biodiesel products and by-products for the domestic market. If backed with adequate location-specific research on crop agronomy and production organization, the cultivation of oil bearing crops such as castor, jatropha and pongamia can contribute to the energy mix in underdeveloped parts of the country. Where the agroecology is suitable and resources such as land and water are available, biodiesel may have economic and environmental benefits in remote villages which lack access to modern energy. However, even in areas where castor and jatropha may be proven to be economically viable or socially desirable, practical realization of the potentials requires the implementation of an efficient organized structure for production, distribution, and marketing. Business models in the form of PPPs can possibly tackle some of the problems. We also suggest exploring opportunities of the Clean Development Mechanism (CDM) for projects that have environmental value, and linking private companies to such financing options to guarantee economic sustainability.

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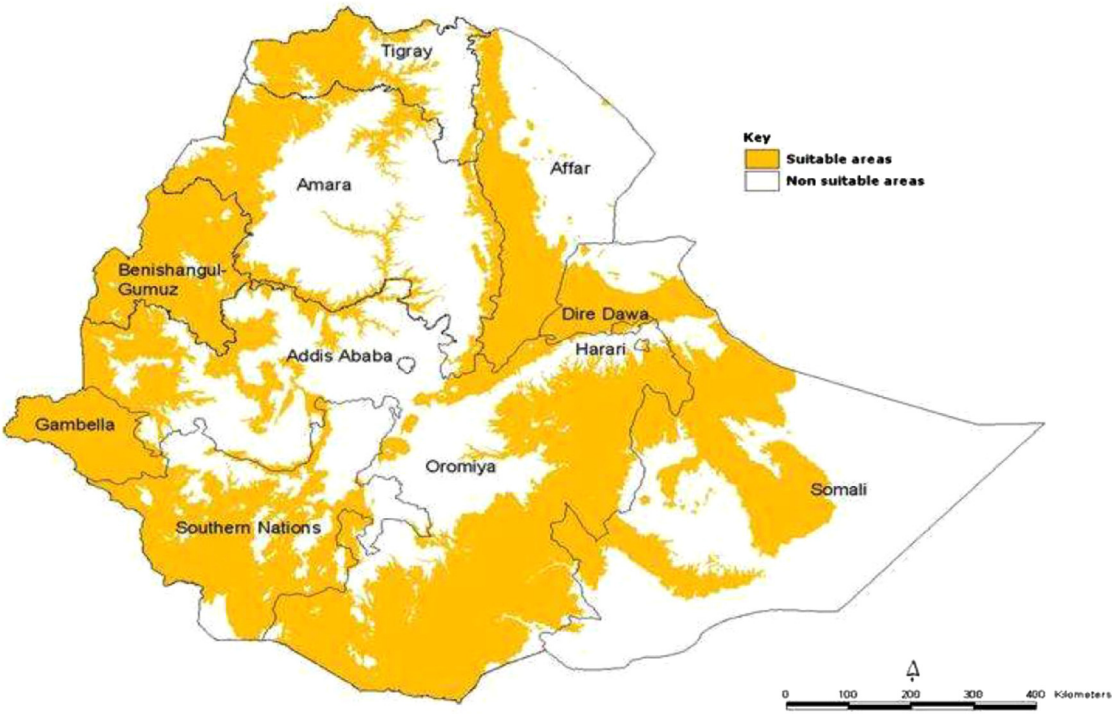

Fig. A1. Suitability map for jatropha. *Note*: The labels in the map refer to the names of the administrative regions of Ethiopia.
Source: [81].

Appendix

See Fig. A1.

References

[1] Bazilian M, Sagar A, Detchon R, Yumkella K. More heat and light. Energy Policy 2010;38:5409–12.
[2] Nussbaumer P, Bazilian M, Modi V. Measuring energy poverty: focusing on what matters. Renewable Sustainable Energy Rev 2012;16:231–43.
[3] Kebede E, Kagochi J, Jolly CM. Energy consumption and economic development in Sub-Sahara Africa. Energy Econ 2010;32:532–7.
[4] Lee C-C, Chang C-P. Energy consumption and economic growth in Asian economies: a more comprehensive analysis using panel data. Resour Energy Econ 2008;30:50–65.
[5] Odhiambo NM. Energy consumption and economic growth nexus in Tanzania: an ARDL bounds testing approach. Energy Policy 2009;37:617–22.
[6] International Energy Agency. World energy outlook 2012—methodology for energy access analysis. Fact Sheets: International Energy Agency 2012.
[7] Amigun B, Musango JK, Stafford W. Biofuels and sustainability in Africa. Renewable Sustainable Energy Rev 2011;15:1360–72.
[8] Neville KJ, Dauvergne P. Biofuels and the politics of mapmaking. Polit Geogr 2012.
[9] MoARD. Biofuel profile. Ministry of Agriculture and Rural Development 2011.
[10] Rajagopal D, Zilberman D. Review of environmental, economic and policy aspects of biofuels. Economic and policy aspects of biofuels (September 1, 2007) World Bank Policy Research working paper; 2007.
[11] Mitchell D. A note on rising food prices. World Bank Policy Research Working Paper Series; 2008.
[12] FAO. Biofuels: prospects, risks and opportunities. The state of food and agriculture. Rome: Food and Agriculture Organization; 2008.
[13] Oladosu G, Msangi S. Biofuel-food market interactions: a review of modeling approaches and findings. Agriculture 2013;3:53–71.
[14] Sovacool BK. The political economy of energy poverty: a review of key challenges. Energy Sustainable Dev 2012.
[15] La Rovere EL, Pereira AS, Simões AF. Biofuels and sustainable energy development in Brazil. World Dev 2011;39:1026–36.
[16] Padula AD, Santos MS, Ferreira L, Borenstein D. The emergence of the biodiesel industry in Brazil: current figures and future prospects. Energy Policy 2012;44:395–405.
[17] Talamini E, de Oliveira L, Gohr CF, Santos LC, Dewes H. Is biodiesel a more social fuel than ethanol? A comparative analysis from public policies in Brazil Afr J Bus Manage 2012;6:9483–95.
[18] Mogues T. The bang for the birr: public expenditures and rural welfare in Ethiopia. J Dev Stud 2011;47:735–52.
[19] Wolde-Ghiorgis W. Renewable energy for rural development in Ethiopia: the case for new energy policies and institutional reform. Energy Policy 2002;30:1095–105.
[20] Erbato TT, Hartkopf T. Smarter micro grid for energy solution to rural Ethiopia. Innovative Smart Grid Technologies (ISGT), 2012 IEEE PES: IEEE 2012:1–7.
[21] Mohammed Y, Mokhtar A, Bashir N, Saidur R. An overview of agricultural biomass for decentralized rural energy in Ghana. Renewable Sustainable Energy Rev 2013;20:15–22.
[22] CSA. Welfare monitoring surveys. Central statistical agency of Ethiopia; 2002–2011.
[23] Maes WH, Verbist B. Increasing the sustainability of household cooking in developing countries: policy implications. Renewable Sustainable Energy Rev 2012;16:4204–21.
[24] WHO. Global burden of disease database. World Health Organization; 2007.
[25] Duflo E, Greenstone M, Hanna R. Indoor air pollution, health and economic well-being. SAPI EN S Surveys and Perspectives Integrating Environment and Society 2008.
[26] International Energy Agency. World energy outlook 2013—modern energy for all; 2013.
[27] MoME. Biofuel development strategy document. Ministry of Mines and Energy of Ethiopia; 2007.
[28] Deininger KW, Byerlee D. Rising global interest in farmland: can it yield sustainable and equitable benefits? World Bank Publications; 2011.
[29] Gebreegziabher Z, Mekonnen A, Ferede T, Guta F, Levin J, Köhlin G, et al. The distributive effect and food security implications of biofuels investment in Ethiopia: a CGE analysis. In: Development Ef, editor. Discussion paper; 2013.
[30] Action aid. Fuel for thought: adressing the social impacts of EU biofuel policies; 2010.
[31] Gaia. Biofuels—a failure for Africa. Gaia Foundation; 2012.
[32] Ejigu A, Asfaw A, Asfaw N, Licence P. Moringa stenopetala seed oil as a potential feedstock for biodiesel production in Ethiopia. Green Chem 2010;12:316–20.
[33] Reubens B, Achten WM, Maes W, Danjon F, Aerts R, Poesen J, et al. More than biofuel? *Jatropha curcas* root system symmetry and potential for soil erosion control J Arid Environ 2011;75:201–5.
[34] Wani SP, Chander G, Sahrawat K, Srinivasa Rao C, Raghvendra G, Susanna P, et al. Carbon sequestration and land rehabilitation through *Jatropha curcas* (L.) plantation in degraded lands. Agric Ecosyst Environ 2012;161:112–20.
[35] Wahl N, Hildebrandt T, Moser C, Lüdeke-Freund F, Averdunk K, Bailis R, et al. Insights into jatropha projects worldwide: key facts & figures from a global survey. University of Luneburg; 2013.
[36] Gaul M. An analysis model for small-scale rural energy service pathways—applied to Jatropha-based energy services in Sumbawa. Indonesia: Energy Sustainable Dev; 2012.

[37] GTZ. Jatropha Reality Check. A field assessment of the agronomic and economic viability of jatropha and other oilseed crops in Kenya. GTZ Regional Energy Advisory Platform (East Africa). Nairobi; 2009.
[38] Hazell PB, Evans M. Environmental, economic and policy aspects of biofuels. In: Markandya A, Galarraga I, editors. Handbook of sustainable energy. Edward Elgar Publishing; 2011. p. 375–92.
[39] Rutz D, Janssen R. Keynote introduction: socio-economic impacts of different scales of biofuel production in Africa. In: Janssen R, Rutz D, editors. Bioenergy for sustainable development in Africa. Springer Science; 2012.
[40] Contran N, Chessa L, Lubino M, Bellavite D, Roggero PP, Enne G. State-of-the-art of the *Jatropha curcas* productive chain: from sowing to biodiesel and by-products. Ind Crops Prod 2013;42:202–15.
[41] Pandey VC, Singh K, Singh JS, Kumar A, Singh B, Singh RP. *Jatropha curcas*: a potential biofuel plant for sustainable environmental development. Renewable Sustainable Energy Rev 2012;16:2870–83.
[42] Ehrensperger A, Portner B, Kiteme B. Potentials and limitations of jatropha curcas for rural energy supply in East Africa: a case study based comparative assessment in Ethiopia, Kenya and Tanzania. IFSA 2012. Aarhus, Denmark; 2012.
[43] Kumar A, Sharma S. Potential non-edible oil resources as biodiesel feedstock: an Indian perspective. Renewable Sustainable Energy Rev 2011;15:1791–800.
[44] Wijnands J, Biersteker J, Loo EN. Oilseeds business opportunities in Ethiopia 2009. Public Private Partnership on Oilseeds (PPP); 2009.
[45] Fisher B, Christopher T. Poverty and biodiversity: measuring the overlap of human poverty and the biodiversity hotspots. Ecol Econ 2007;62:93–101.
[46] Kramer DB, Urquhart G, Schmitt K. Globalization and the connection of remote communities: a review of household effects and their biodiversity implications. Ecol Econ 2009;68:2897–909.
[47] Kuchler M, Linnér B-O. Challenging the food vs. fuel dilemma: genealogical analysis of the biofuel discourse pursued by international organizations. Food Policy 2012;37:581–8.
[48] von Maltitz GP, Setzkorn KA. A typology of Southern African biofuel feedstock production projects. Biomass Bioenergy 2013;59:33–49.
[49] HLPE. Biofuels and food security. A report by the high level panel of experts on food security and nutrition of the committee on world food security. Rome: FAO; 2013.
[50] Altenburg T. Interest groups, power relations, and the configuration of value chains: the case of biodiesel in India. Food Policy 2011;36:742–8.
[51] Cabral L, Scoones I. Narratives of agricultural policy in Africa: what role for Ministries of Agriculture. Future Agric 2006.
[52] Peidong Z, Yanli Y, Yongsheng T, Xutong Y, Yongkai Z, Yonghong Z, et al. Bioenergy industries development in China: dilemma and solution. Renewable Sustainable Energy Rev 2009;13:2571–9.
[53] Yang J, Dai G, Ma L, Jia L, Wu J, Wang X. Forest-based bioenergy in China: status, opportunities, and challenges. Renewable Sustainable Energy Rev 2013;18:478–85.
[54] Meerman J. Reforming agriculture: the World Bank goes to market. World Bank Publications; 1997.
[55] Clark S, Thompson S. Policy context & rationale for intervention in the agri-food sector. Canadian Agri-Food Policy Institute—Advancing Policy Institute; 2011.
[56] Baumann P. Equity and efficiency in contract farming schemes: the experience of agricultural tree crops. ODI working paper 2000:139.
[57] Arndt C, Msangi S, Thurlow J. Are biofuels good for African development? An analytical framework with evidence from Mozambique and Tanzania Biofuels 2011;2:221–34.
[58] Ewing M, Msangi S. Biofuels production in developing countries: assessing tradeoffs in welfare and food security. Environ Sci Policy 2009;12:520–8.
[59] Minten B, Randrianarison L, Swinnen JF. Global retail chains and poor farmers: evidence from Madagascar. World Dev 2009;37:1728–41.
[60] Suzuki A, Jarvis LS, Sexton RJ. Partial vertical integration, risk shifting, and product rejection in the high-value export supply chain: the Ghana pineapple sector. World Dev 2011;39:1611–23.
[61] Dubois O. Making sure that biofuel development benefits small farmers and communities. . Unasylva (FAO); 2008; 25–32.
[62] Jumbe CB, Mkondiwa M. Comparative analysis of biofuels policy development in Sub-Saharan Africa: the place of private and public sectors. Renewable Energy 2013;50:614–20.
[63] Poulton C, Macartney J. Can public–private partnerships leverage private investment in agricultural value chains in Africa? A preliminary review World Dev 2012;40:96–109.
[64] Locke A, Henley G. Scoping report on biofuels projects in five developing countries. London: Overseas Development Institute; 2013.
[65] Beyene A, Matondi PB, Havnevik K. Smallholder-led transformation towards biofuel production in Ethiopia. In: Matondi PB, Havnevik K, Beyene A, editors. Biofuels land grabbing and food security in Africa; 2011. p. 90–105.
[66] IPCC. Summary for policymakers of climate change 2007: mitigation. Contribution of working group III contribution to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press; 2007.
[67] Michaelowa A, Jotzo F. Transaction costs, institutional rigidities and the size of the clean development mechanism. Energy Policy 2005;33:511–23.
[68] Lal R. Land area for establishing biofuel plantations. Energy Sustainable Dev 2006;10:67–79.
[69] Spalding-Fecher R, Achanta AN, Erickson P, Haites E, Lazarus M, Pahuja N, et al. Assessing the impact of the clean development mechanism. Report commissioned by the high-level panel on the CDM policy dialogue CDM policy dialogue. Available online at ⟨http://www.cdmpolicydialogueorg/research/1030_impact.pdf⟩; 2012.
[70] UNDP. CDM opportunities and challenges in Ethiopia. United Nations Development Program 2007.
[71] Hoch S. Governing clean development in LDCs: do CDM rules promote renewable energy in Ethiopia? The governance of clean development—working paper series. School of International Development: Univeristy of East Anglia, UK.
[72] Kuik OJ, Lima MB, Gupta J. Energy security in a developing world. Wiley Interdiscip Rev Clim Change 2011;2:627–34.
[73] Sovacool BK. Deploying off-grid technology to eradicate energy poverty. Science 2012;338:47–8.
[74] European Commission. New commission proposal to minimize the climate impacts of biofuel production. IP/12/1112: European Commission; 2012.
[75] Negash M, Swinnen JF. Biofuels and food security: micro-evidence from Ethiopia. Energy Policy 2013;61:963–76.
[76] Johansson S, Belfrage K, Olsson M. Impact on food productivity by fossil fuel independence—a case study of a Swedish small-scale integrated organic farm. Acta Agric Scand Sect B—Soil Plant Sci 2013;63:123–35.
[77] WEC. Biofuel: policies, standards and technologies. World Energy Council; 2010.
[78] Phalan B. The social and environmental impacts of biofuels in Asia: an overview. Appl Energy 2009;86:S21–9.
[79] Mulugetta Y. Evaluating the economics of biodiesel in Africa. Renewable Sustainable Energy Rev 2009;13:1592–8.
[80] Negash M, Swinnen JF. Biofuels and food security: micro-evidence from Ethiopia. Energy Policy 2013 (Forthcoming).
[81] MoME. Biofuel development strategy for Ethiopia—volume II, potential assessment for a biodiesel industry in Ethiopia. First draft report: Ministry of Mines and Energy of Ethiopia; 2007.